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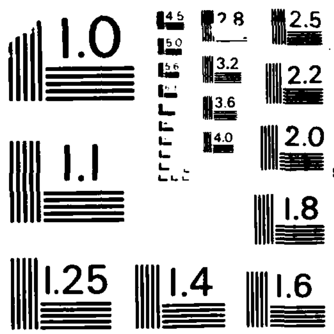

MICROCOPY RESOLUTION TEST CHART
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Over the first year of this effort considerable attention was devoted to the development of a novel tunable femtosecond source and to the temporal resolution improvement of the electro-optic sampling technique. The technique was applied to the measurement of the response time of such fast semiconductor devices as the MESFET and the TEGFET.

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AFOSR-TR- 87-0746

Annual Technical Report

APPLICATIONS IN SUBPICOSECOND SPECTROSCOPY

AFOSR Contract #84-0318

For Period Ending September 1985

One of the goals of this project was to directly observe the nonsteady state carrier transport in bulk materials and heterostructures. Lately, we have been attempting to directly time-resolve carrier velocity overshoot in GaAs using femtosecond optical techniques. The principle of the experiment is shown in Fig. 1. Carriers are produced in a sample of GaAs by femtosecond optical pulses wavelength-tuned ideally at the band gap. The photocurrent, I(t), is proportional to the number of photocarriers, N, the charge of the electron, (e), and the velocity, v(t). The photocurrent was time-resolved using the electro-optic sampling technique. Because the velocity overshoot occurred in the subpicosecond time scale, the direct investigation of this phenomenon necessitated tunable femtosecond optical pulses in the near IR as well as subpicosecond waveform characterization capabilities.

Over the first year, an extensive amount of work was devoted to the demonstration of a novel femtosecond tunable source and to the temporal resolution improvement of the electro-optic sampling technique. In addition, the response of fast devices such as the MESFET and TEGFET was studied in an attempt to measure the carrier transit time through the control region.

(A) The tunable femtosecond high repetition rate source (Fig. 2)

As shown in Fig. 2, the system was based on a Nd:YAG, cw-pumped mode-locked dye laser which provides < 80 fs optical pulses. Some of the 1.06 μm light was reamplified by a regenerative amplifier. The regenerative amplifier provides a pulse at 1 kHz of 1 mJ energy perfectly synchronized with the short pulses delivered by the

oscillator. After frequency doubling, the pulses pump a two-stage amplifier. At the output of the second stage the energy per pulse is > 1 μJ at 1 kHz. The autocorrelation traces of the amplified input and output appear in Figs. 3 and 4. The peak power is high enough when focused in a water cell to generate white light continuum, so ultrafast spectroscopy can be done over the entire visible spectrum. The amplification of part of the continuum is shown in Fig. 5 by means of an auxiliary dye cell pumped with the remains of the second harmonic. Pump and probe experiments at different wavelengths can for the first time be made at this repetition rate.

(B) Waveform characterization with few hundred femtosecond resolution

Parallel to the effort on tunable short amplified pulses, an extensive amount of work has been done in the area of electro-optic sampling. We have demonstrated that by using a coplanar stripline, a waveform with 400 fs features could be time resolved.

(C) High speed device characterization

We have also shown that the technique of electro-optic sampling could be applied to the characterization of transistors such as MESFET and TEGFET. The experimental set up is shown in Fig. 6. A short pulse excites a photoconductive switch to produce a fast step function which is applied to the gate of the transistor. The collector output was connected to a transmission line built on electro-optic material. The result showed the transistor response for MESFET and TEGFET under low gain condition. Rise times of 25 ps for the MESFET and 17 ps for the TEGFET have been observed. The TEGFET results agree very well with ring oscillator data, where a gate delay of 18 ps has been observed for the same type of device.

PUBLICATIONS

T. Norris, T. Sizer II, and G. Mourou, "Generation of 85-fsec Pulses by Synchronous Pumping of a Colliding-Pulse Mode-Locked Dye Laser," J. Opt. Soc. Am. B 2, 613-614 (April 1985).

I. N. Duling III, T. Norris, T. Sizer II, P. Bado, and G. A. Mourou, "Kilohertz Synchronous Amplification of 85-Femtosecond Optical Pulses," J. Opt. Soc. Am. B 2, 616-618 (April 1985).

D. R. Dykaar, T. Y. Hsiang, and G. A. Mourou, "An Application of Picosecond Electro-Optic Sampling to Superconducting Electronics," IEEE Trans. Magn. 21, 230-233 (March 1985).

K. E. Meyer and G. A. Mourou, "Two-Dimensional E-Field Mapping with Subpicosecond Temporal Resolution," Electron. Lett. 21, 568-569 (June 1985).

K. E. Meyer and G. A. Mourou, "Two Dimensional E-Field Mapping with Subpicosecond Resolution," in Picosecond Electronics and Optoelectronics, edited by G. A. Mourou, D. M. Bloom, and C. H. Lee (Springer-Verlag, New York, 1985), pp.46-49.

K. E. Meyer, D. R. Dykaar, and G. A. Mourou, "Characterization of TEGFETs and MESFETs Using the Electrooptic Sampling Technique," in Picosecond Electronics and Optoelectronics, edited by G. A. Mourou, D. M. Bloom, and C. H. Lee (Springer-Verlag, New York, 1985), pp. 54-57.

S. Williamson and G. A. Mourou, "Picosecond Electro-Electron Optic Oscilloscope," in Picosecond Electronics and Optoelectronics, edited by G. A. Mourou, D. M. Bloom, and C.H. Lee (Springer-Verlag, New York, 1985), pp. 58-61.

C. J. Kryzak, K. E. Meyer, and G. A. Mourou, "Transmission Line Designs with a Measured Step Response of 3 ps Per Centimeter," in Picosecond Electronics and Optoelectronics, edited by G. A. Mourou, D. M. Bloom, and C. H. Lee (Springer-Verlag, New York, 1985), pp. 244-248.

PARTICIPATING PROFESSIONALS

In order to time resolve in the subpicosecond time scale, the velocity overshoot and tunable ultrafast optical source had to be demonstrated, and the temporal resolution of the electro-optic sampling technique used in this experiment had to be improved to the hundred femtosecond level. A large number of people, graduate students essentially, have been involved either in the source development or electro-optic sampling improvement. The people involved in this research have been:

Professors: G. Mourou and T. Castner (University of Rochester); R. Grondin (University of Arizona)

Graduate Students: T. Norris, K. Meyer, I. Duling, and M. Pessot (University of Rochester)

INTERACTION AND COUPLING ACTIVITIES

All the Monte Carlo modeling has been performed at the University of Arizona by Professor Grondin's group. The Rochester group has been very active in encouraging the interaction between the field of ultrafast optics and high-speed electronics; we participated in the birth of the conference on picosecond electronics and optoelectronics that took place in Lake Tahoe in March 1985. The group has interacted extensively with other departments at the University of Rochester: Electrical Engineering, Institute of Optics, and Physics. We have interacted with other universities, such as Cornell University, which has provided us with some MESFET devices. The group has interacted with laboratories such as MIT Lincoln Laboratory in the characterization of the Permeable Base Transistor and Thomson-CSF for the TEGFET characterization.

A number of seminars and conferences were given on the general subject of ultrafast optics for electronics. I gave presentations at the following:

- University of Arizona	January 24
- IBM - Yorktown Heights	February 25
- Picosecond Electronic & Optoelectronic, Lake Tahoe	March 13
- Bell Laboratory - Murray Hill	April 9
- Bell Laboratory - Holmdel	April 10
- MIT	April 24
- Cerdon. Conference - New Hampshire	July 30
- CLEO - Baltimore	May 22
- Lincoln Laboratory	September 6
- Universite Laval - Quebec	September 19
- Princeton University	September 23
- Siemens - Princeton	September 24
- Notre Dame	October 20
- American Institute of Physics Corporate Associate Meeting	October 23
- Lawrence Livermore National Laboratory	October 29

-	Optical Bistability Conference - Tucson, Arizona	December 3
-	Physics of Ultrasmall Devices - Tempe, Arizona	December 9

Time-Resolved Velocity Overshoot Measurement in the Femtosecond Time Scale

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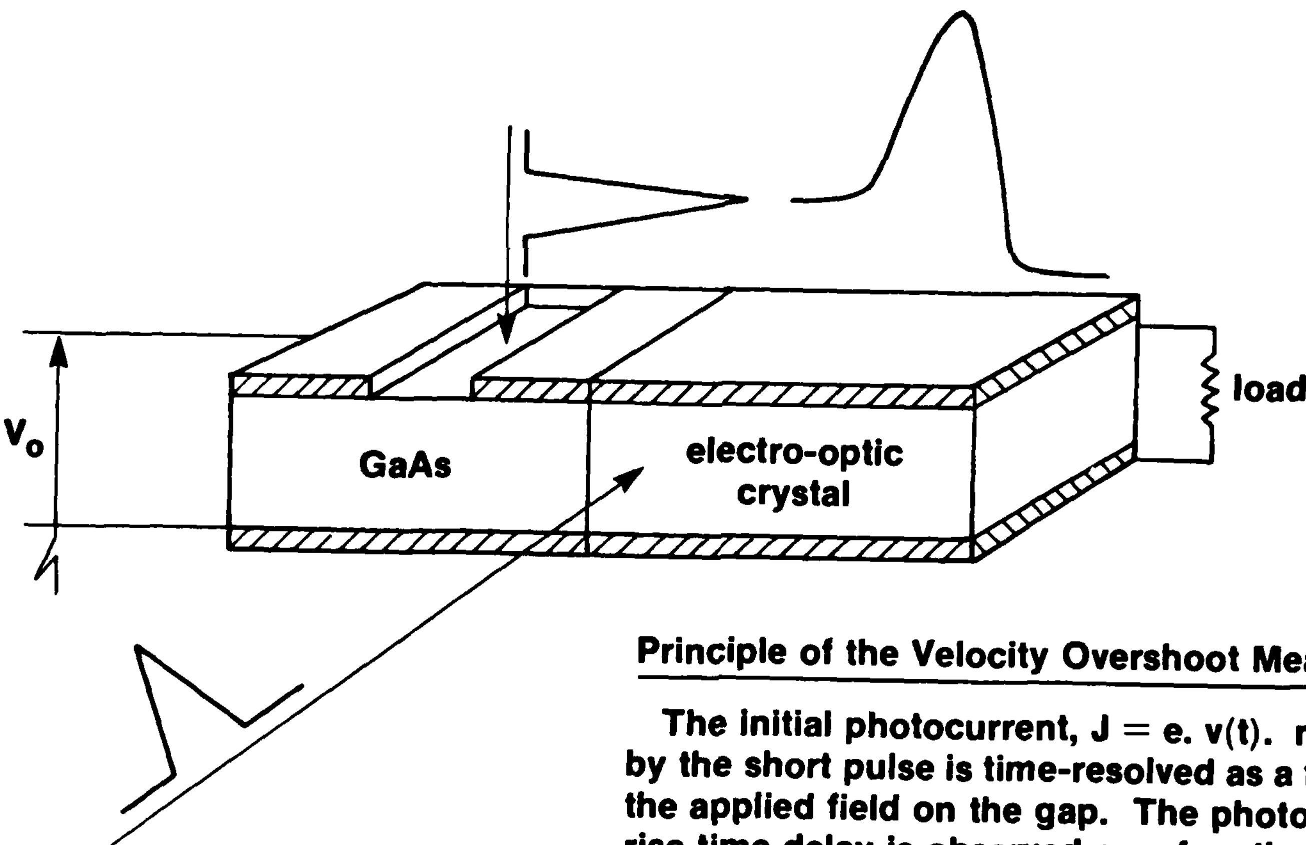

Principle of the Velocity Overshoot Measurement

The initial photocurrent, $J = e.\ v(t).\ n$ produced by the short pulse is time-resolved as a function of the applied field on the gap. The photocurrent rise time delay is observed as a function of of the E-field.

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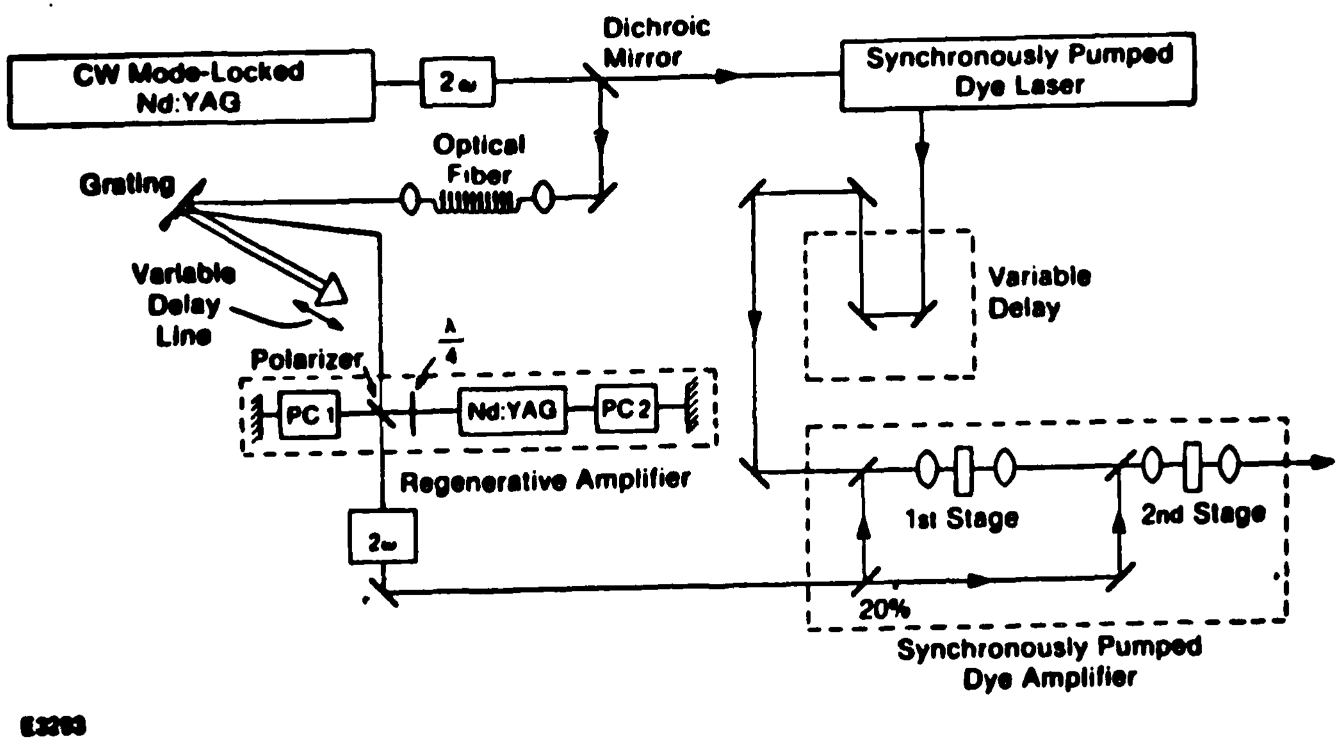
Figure 1

KILOHERTZ SYNCHRONOUS DYE AMPLIFIER SYSTEM



System characteristics
- *pulse width < 100 fs*
- repetition rate 1 KH$_z$
- energy/pulse 2 μJ
- tunable by generation of continuum

Figure 2

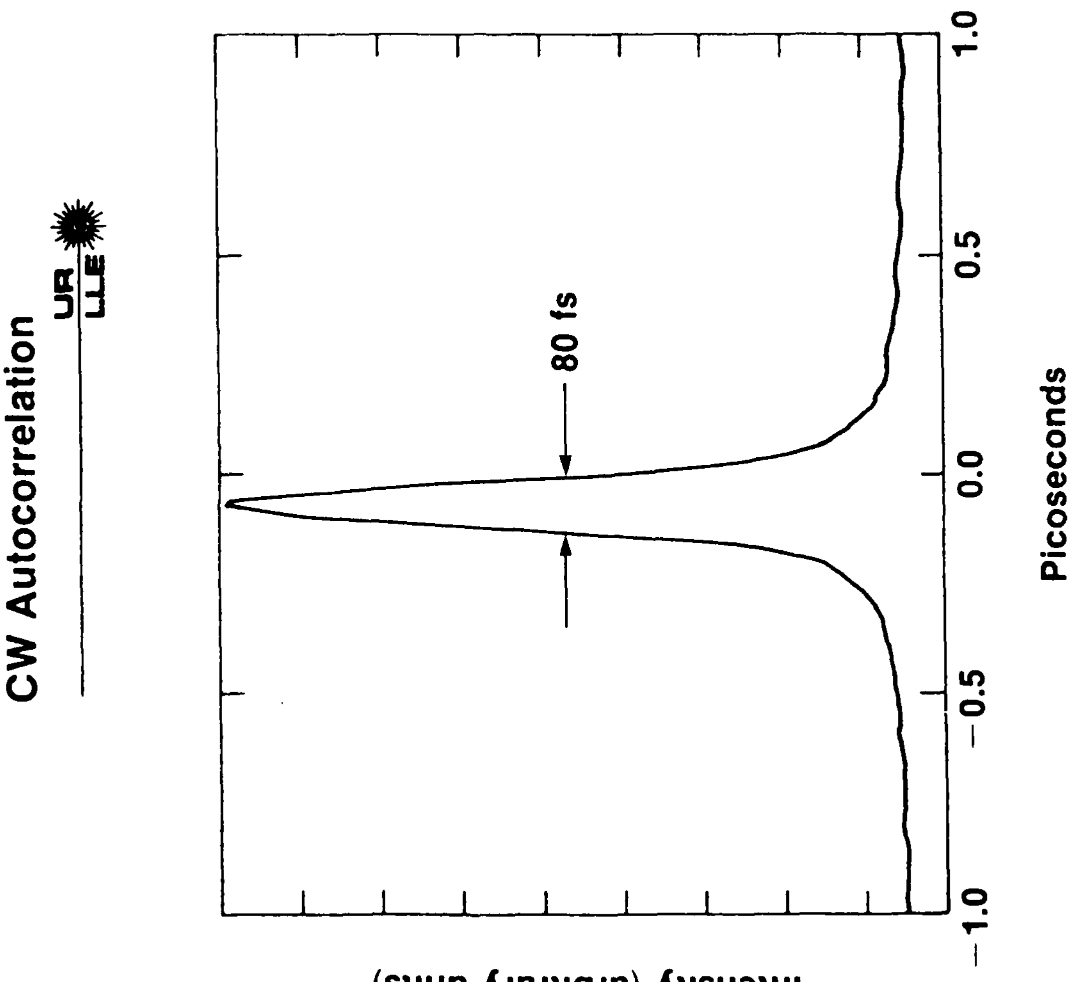


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Figure 3

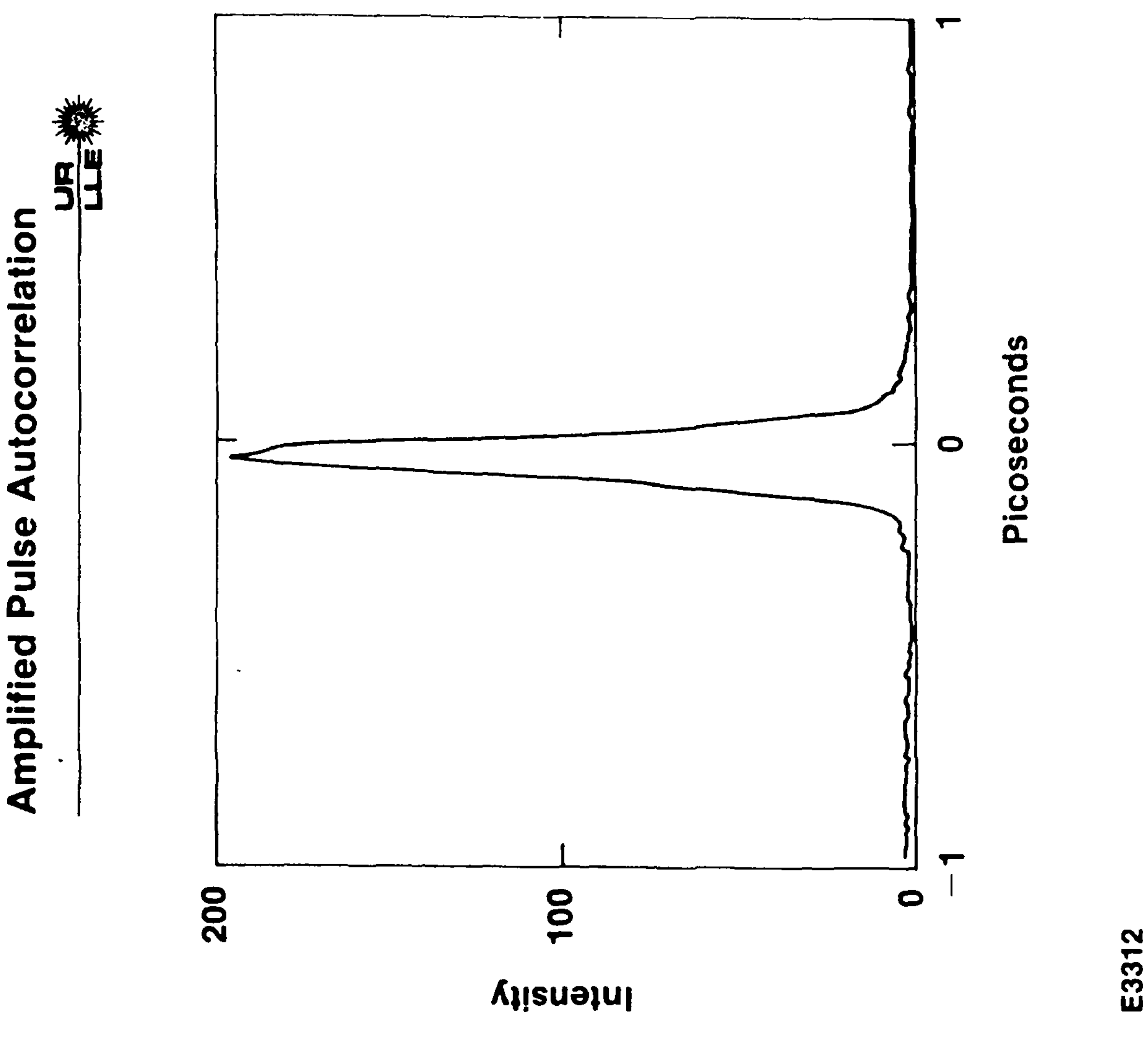

Amplified Pulse Autocorrelation
UR
LLE
Intensity
200
100
0
−1
0
1
Picoseconds
E3312

Figure 4

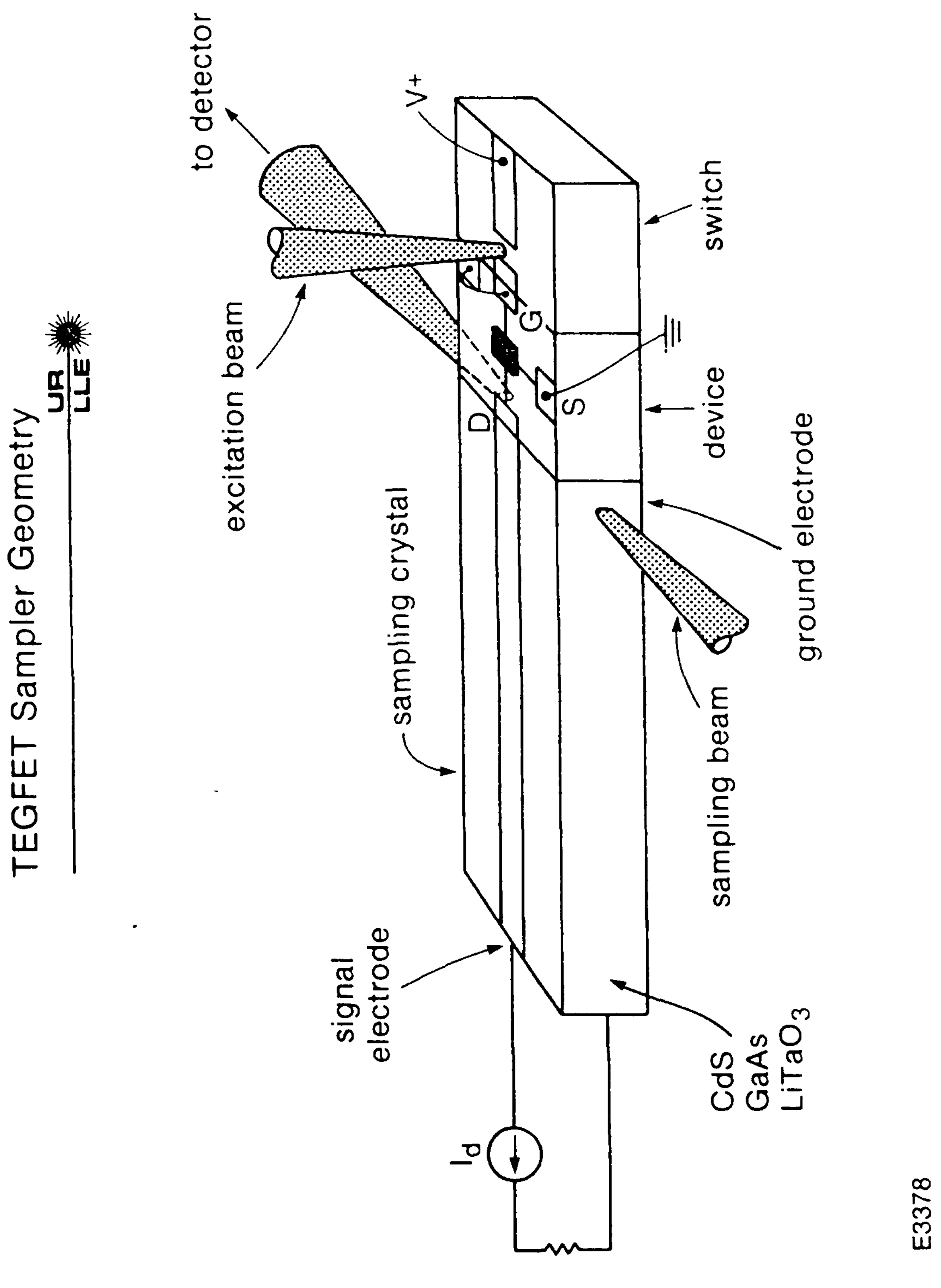
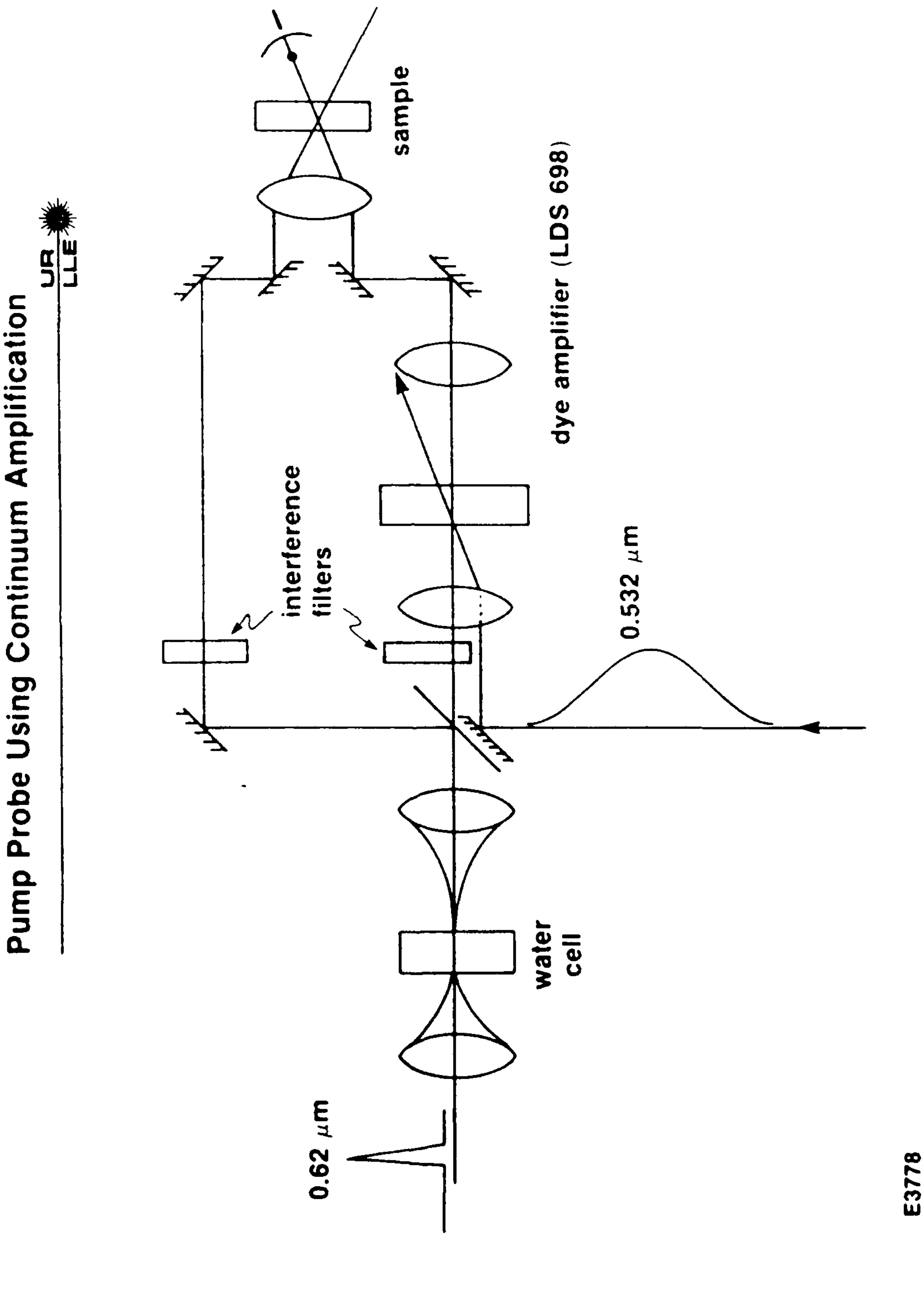

TEGFET Sampler Geometry
to detector
V+
excitation beam
G
D
S
switch
device
ground electrode
sampling crystal
sampling beam
signal
electrode
CdS
GaAs
$LiTaO_3$
I_d
E3378

Figure 5



Pump Probe Using Continuum Amplification
UR
LLE
sample
dye amplifier (LDS 698)
interference
filters
0.532 μm
water
cell
0.62 μm
E3778

Figure 6

END
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